Digital mapping of pruning weight in vineyards in the frame-work of precision viticulture

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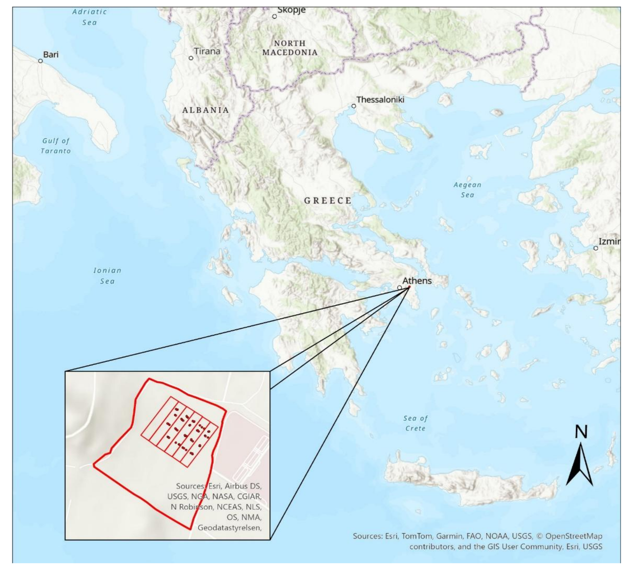
Abstract

This study showcases the potential of utilizing LiDAR sensing technologies as an automated, efficient, and rapid method for mapping winter pruning wood across vine-yards. It was conducted in 2024 in a commercial vineyard in the region of Attica in Greece in the framework of "AGROSYS" project. The experimental area was 3.5 ha grown with Savvatiano variety. Cane weight data were collected manually at pruning, while soil spatial variability, and canopy properties were mapped and analysed. The regression analysis of the three-dimensional point clouds and the manual measurements of pruning weight revealed a strong relationship. This signifies the high potential of accurate mapping of dormant pruning canes across vineyards using rapid and time-efficient digital methods. The analysis also revealed strong relationships with the NDRE and canopy temperature at harvest.

Objectives

- To evaluate the utilisation of applying PV practices and digital technologies in a commercial vineyard in the region of Attica in Greece.
- To investigate the potential of SLAM LiDAR scanner to map and quantify the dormant pruning canes in orchards.
- To evaluate the relationship between dormant pruning and canopy parameters at veraison and harvest

Methodology



- The experimental area was 3.5 ha, located in Attica in Greece grown with Savvatiano (Vitis vinifera L.)
- The soil ECa was mapped, and a DEM was prepared utilizing measurements from an RTK-GNSS.
- Analysis of ECa resulted in the delineation of soil zones based on which 26 sample vines were selected.
- The sample vines were measured for their physiological status utilizing proximal sensing.
- Vine canopy reflectance was measured with ground-based (CropCircle – Holland Scientific) on UGV and aerial-based UAV systems (MAVIC 3M multispectral with RTK GNAA - DJI) during Veraison and Harvest.
- A handheld (IR) thermal camera (FLIR Systems, Inc.) was utilized to measure canopy temperature as an assessor of the vines' reaction to water scarcity and heat stress
- The pruning canes scanning process occurred in February 2025 at dormancy stage using a 3D SLAM LiDAR scanner. The point cloud was analysed with the FJD Trion Model processing software
- Linear regression analysis was performed to reveal the relationship between the measured parameters.

Conclusions

- Mapping the soil ECa, confirmed the hypothesis that soil spatial variability is a reliable factor that determines the spatial variability of grapevines' growth and physiology throughout vineyards.
- The method described in this study provides rapid mapping of the 3D representation of vines.
- The analysis of the 3D point clouds of the sample vines provided an accurate estimation of the dormant canes which is a reliable indicator of within season vine vigour.
- The potential of 3D mapping to accurately assess spatial variability of vine status was highlighted, making the LiDAR 3D scanners a valuable tool for characterizing within-vineyard variability.
- this technology shows limitations that are related to the complexity of data acquisition and analysis and the large volume of data that need to be stored and processed.
- Further studies are required to enrich the dataset and improve the efficacy. The relationship between LiDAR sensor data and thermal measurements should be further investigated under different climatic conditions through multiple site-years.

Results

The sample vines were isolated from the 3D point cloud of the experimental area and the count of the total points in each vine was estimated as the metric of growth.

Figure 1. 3D point cloud from the experimental vineyard with annotated sample vines.

Descriptive statistics:

- The initial hypothesis that soil variability produces spatial variability on vine development was confirmed; the descriptive statistics of the point cloud measurements of the sample vines showed considerably high coefficient of variation (CV=37%).

Regression Analysis:

- The count of the total points per vine was used as dependent variable in the regression analysis with the rest of the measured parameters. The results revealed a strong positive relationship between the points count and the pruning canes weight (R2=0.65).
- strong relationship was observed among the LiDAR scans and the leaf temperature measured using a thermal camera during harvest (R2=0.64).
- Weaker relationship between the same parameters, yet significant (R2=0.41), was also observed with the canopy temperature measured at veraison. This is attributed to the water status in July when the vines were less stressed and, thus, the range of the temperature measurements was shorter, and the variability was low. The negative relationship indicates that the more vigorous vines had better reaction to heat and water scarcity stress.

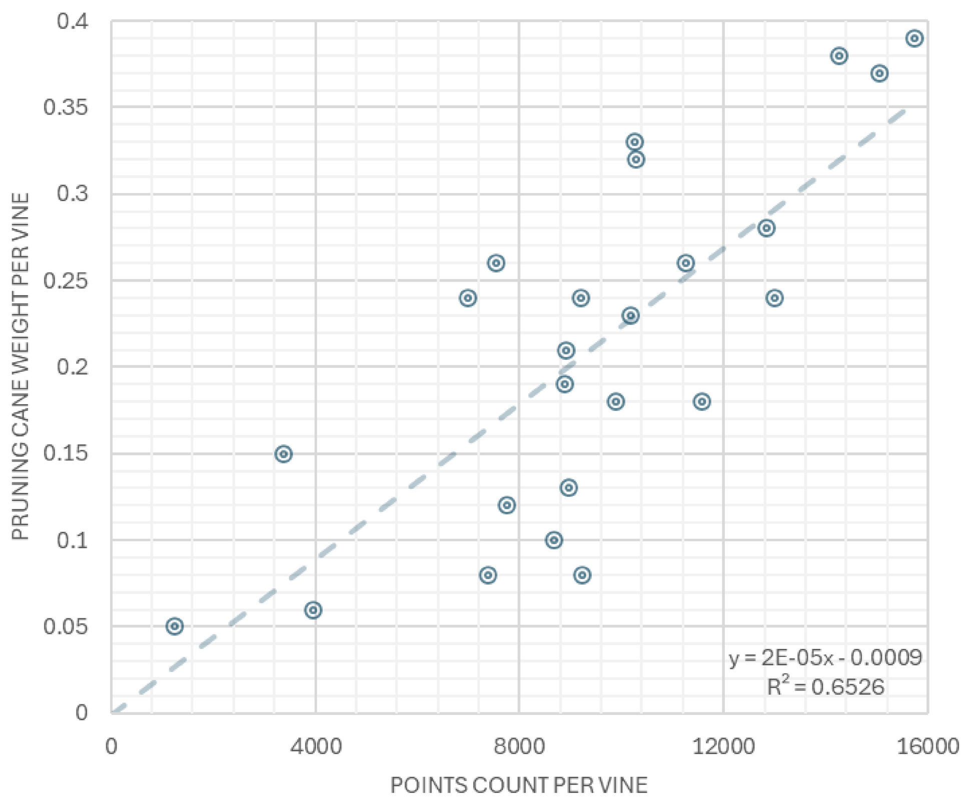


Figure 2. Regression between point cloud counts and measured weight of pruning canes per sampling vine.

Table 1. Regression analysis between pruning canes estimation from 3D model and other measured parameters

Measurement	Relationship	Coefficient of Determination (R2)
NDVI at harvest	positive	0.19
NDRE at harvest	positive	0.56
Thermal at harvest	negative	0.64
Thermal at veraison	negative	0.41

- NDRE vegetation index measured at harvest had a stronger relationship with pruning measurements (R2=0.56) as compared to the NDVI (R2=0.19) supported by the fact that the NDVI is saturated at dense canopies making NDRE more appropriate indicator of canopy variability at such conditions.

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